

MLCP: Multi level Clustering Protocol in Wireless Sensor Network

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May 28, 2013

Certificate

This is to certify that the work in the project entitled *Multi level Clustering Protocol in Wireless Sensor Network* by *Takhellambam Sonamani Singh* is a record of an original work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Master of Technology* in *Computer Science and Engineering*. Neither this project nor any part of it has been submitted for any degree or academic award elsewhere.

Suchismita Chinara

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Abstract

The basic goals of wireless sensor network are to enhance the lifetime of the network and also to use the energy of the network nodes efficiently. There are so many traditional approaches or techniques available in wireless sensor network (WSN) to achieve the above goals. But, they are not so efficient and reliable in terms of utilization of energy of the nodes in the network. Thus, Clustering is one of the key techniques to achieve the above goals in wireless sensor network with less energy consumption. It can also increase network scalability. Sensor nodes are typically considered to be homogeneous in nature since the researches in the field of wireless sensor networks have been evolved but in reality, homogeneous sensor networks hardly exist. Thus, we require a clustering technique which will work in heterogeneous environment which are more closely associated with real life scenarios. In this thesis, investigations have been made to design a heterogeneous aware clustering technique named "Multi level clustering protocol" (MLCP) in wireless sensor network in order to ensure the protocol to closely work with the real life situations. The main objective of the Multi level clustering protocol (MLCP) is to extend the stable region of wireless sensor nodes, which finally increases the life time of the network with efficient energy usage. The protocol classified the nodes into different types in term of their energy levels. Finally, the simulation result shows that MLCP gives better performance than the existing system, Low Energy Adaptive Clustering Hierarchy (LEACH) and Distributed Election Clustering (DEC) protocol.

There are two variants of Multi level Clustering protocol (MLCP). They are Multi level Election Clustering Protocol ((MLECP)) and Multi level Randomized Clustering Protocol (MLRCP).

Multi level Election Clustering protocol ((MLECP)) has been proposed to increase the stable region of the network which finally increases the life time of the network with efficient energy usage. In this protocol, we consider a more heterogeneous aware environment where there are 3 level nodes and 4 level nodes energy. The CH selection in this scheme is based on the ratio of the current remaining energy of the node divided by the number of its neighbours to the sum of all its neighbours nodes current energy including itself and its communication cost to its neighbouring nodes within a certain transmission range.

Multi level Randomized Clustering Protocol (MLRCP) has been designed to enhance the stable region of the network and finally increases the life time of the

network with efficient energy usage. In this protocol, the existing system LEACH protocol is being improved so as to enable working in heterogeneous environment. It is done by classifying the nodes of the network into different category in term of their energy levels namely, 2 level nodes, 3 level nodes and 4 level nodes. The cluster head(CH) selection is based on the random number generated by the node and its comparison with the threshold value of that node.

Verification for the above two protocols are made through simulation by using the Matlab tools.

Keywords: Stable region, life time, homogeneity, heterogeneity, cluster head(CH), Residual Energy.

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Chapter 1

Introduction

The wireless sensor networks have been used in a wide range of both civilian and military applications and the sensor nodes limited capacity has posed many challenges in the design issues. The resources such as communication bandwidth and the energy are more limited than those in a traditional wireless sensor network. This limitation requires any design protocols and technique to use the resources available effectively and efficiently. In this thesis, we described about the design of clustering protocol for wireless sensor networks considering the energy consumption issues as the main constraint. Various clustering techniques have been designed for wireless sensor networks in the past. Although many of these techniques performed effectively in many aspects, there are still some areas which are to be addressed in these techniques.

The goals of this thesis are:

1. To design an energy efficient clustering technique for wireless sensor networks
2. To verify the correctness of the designed clustering technique on a competent simulation platform.

1.1 Introduction to Wireless Sensor networks

Advances in micro-electromechanical systems, radio and memory technologies and processors have enabled the fast development of wireless sensor networks [1–4]. Figure 1.1(a) and 1.1(b) represents the typical structure of a wireless sensor

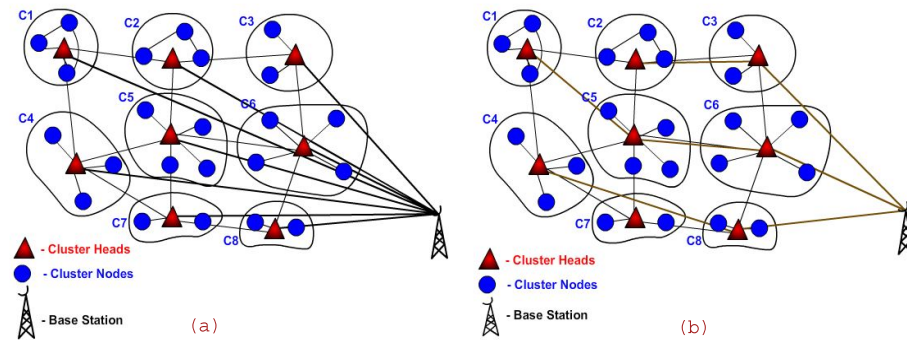


Figure 1.1: (a)Single-hop clustering,(b)Multi-hop clustering

network with single-hop and multi-hop clustering. In the single-hop clustering, each node will send data to the BS. On the other hand, multi-hop clustering will have some CH's nodes in between the ordinary nodes and BS through which data transmission of the network to the BS takes place. Various sensor nodes are being scattered in an area of interest with a BS located at a specific location of the network area. Each node in the network field must send the high-quality description of events to the sink in order to achieve remote monitoring of an environment through which end-users can communicate the network system through satellite, Internet or wireless communication means.

Wireless sensor networks have thus become a new tool for extracting data from the environment. WSN allows the sensor nodes to be deployed as fixed in the monitoring field [5–7]. In addition, the wireless sensor nodes communicate to the base station through a wireless network model instead of directly communicating through a wired means. So, wireless sensor networks are more convenient and flexible for getting data from the monitoring environment. The conventional wired sensor network nodes are very costly and involve large amounts of energy for the network operation. Also, the deployment of these nodes is very expensive.

Therefore, it will be a good idea and feasible to replace these nodes with low-cost nodes which can be easily operated. Wireless sensor networks are fault-tolerant.

Wireless sensor network have been used in a wide range of applications, such as machine failure diagnosis, environment monitoring and biomedical purpose [8–11]. But, the physical constraints of sensor nodes posed many challenging issues in designing the wireless sensor networks. Some of the constraints which may affect the design of wireless sensor networks are as follows-

1. Limited energy supply. The energy of a sensor node which is initially installed with a battery as the power supply is very limited [12]. The energy of the network is consumed while data processing and data transmission of the nodes takes place. So, it is easy to drain the energy of the node at the time of network operation. The problem of energy drain out is further aggravated by some nodes that are given no attention. For example, in a specific application, sensor nodes are found to be scattered in a very dangerous and inaccessible territory. Recharging or replacing the batteries of such nodes are impossible. Also, to substitute all the batteries of nodes in a large area can be very costly and unreasonable. So, managing limited energy of a node is the most very important and crucial challenging issue for the design of wireless sensor networks.
2. Limited transmission range. The sensor node's transmission range is very much limited due to the constraint of node energy and antenna capability [13,14]. The maximum reachable location of a sensor node is comparatively small with the traditional wireless network even though some nodes are able to vary their power level [7,15]. Therefore, large numbers of sensor nodes have to be deployed for many applications in order to ensure the good coverage of the network. Also, the limited transmission range ensures the requirements of high node density for the purpose of maintaining connection between the nodes as reliable.
3. Small storage size. The storage capacity of a sensor node is very small as compared to that of traditional networks. This limitation makes the nodes

to be unsuitable for applications where there are requirements of large storage capacity. Also, small capacity of storage will lead to very small communicating and processing capabilities.

1.2 Routing Challenges and Design Issues

Depending on the application, different architectures and design goals have been designed for sensor networks since the performance of a routing protocol is closely related to the architectural model-

1. Network dynamics- Most of the network architectures assume that sensor nodes are stationary, because there are very few setups that utilize mobile sensors. It is sometimes necessary to support the mobility of sinks or cluster-heads. Route stability becomes an important optimization factor, in addition to energy, bandwidth etc. The routing messages from or to moving nodes is more challenging. So, the sensed event can be either dynamic or static depending on the application.
2. Node deployment- It is application dependant that affects the performance of the routing protocol. The deployment is either deterministic or self-organizing. In deterministic deployments, the sensors are placed manually and data is routed through a fixed-determined paths. On the other hand, in self-organizing systems, the sensor nodes are scattered randomly creating an infrastructure in an adhoc manner.
3. Energy Considerations- During the creation of an infrastructure, the process of setting up the routes is greatly influenced by energy considerations. As the transmission power of a wireless radio is directly proportional to the distance squared or even higher order in the presence of obstacles, multi-hop routing will consume less energy than direct transmission. However, multi-hop routing incurs significant overhead for management in topology and medium access control. Direct routing would perform well enough if all the nodes

were very close to the sink. Sensors are scattered randomly over an area of interest and multi hop routing becomes unavoidable.

4. Data delivery models- Data delivery models to the sink can be continuous, event driven, query-driven and hybrid, depending on the application of the sensor network.
5. Node capabilities- In a sensor network, different functionalities can be associated with the sensor nodes. Depending on the application, a node can be dedicated to a particular special function such as relaying, sensing and aggregation since engaging the three functionalities at the same time on a node might quickly drain the energy of that node.
6. Data aggregation/fusion- Similar packets from multiple nodes can be aggregated to reduce the transmission. For this sensor nodes might generate significant redundant data. Data aggregation is the combination of data from different sources using functions such as suppression, min, max and average.

1.3 Objective

The main objective of this thesis are-

1. To identify the existing clustering techniques in wireless sensor network and implement atleast some of them
2. To design and develop a new proposed clustering technique which helps to extend the stable region of the wireless sensor nodes which finally increases the life time of the network and the efficient energy usage.
3. To analyse and verify the performance of the proposed clustering protocol using a simulator Matlab.
4. To compare the proposed method with the existing algorithms based on the no. of nodes alive in each of the rounds of the network.

1.4 Motivation

The design of the clustering technique in Wireless sensor network is influenced by the limited power of the battery that mandate to design the energy efficient clustering protocol. Much researches has been done in the recent past investigating different aspects like low power protocol, network establishment, coverage problems and the establishment of reliable wireless sensor networks. But, even after many efforts, there are still design options open for improvement. This leads to motivate me to devise a new protocol which enables more efficient use of scare resources at individual sensor nodes for an application.

1.5 Thesis organization

This thesis begins with the introduction in Chapter 1. A detailed description of background or related work, especially clustering technique for wireless sensor networks, is presented in Chapter 2. Chapter 3 describes about the details of our clustering technique i.e. the Multi-level clustering protocol(MLCP). Chapter 3 also describes about the network and energy model used in our clustering technique. We evaluate the performance of our clustering protocol by comparing with other existing clustering protocols using a MATLAB simulator in Chapter 4. This thesis concludes with a discussion of future scope or directions in Chapter 5.

Chapter 2

Background and Literature

Review

2.1 Network Layer Routing Protocol

According to the OSI model, Routing protocol is a network layer protocol [16,17]. With a specific protocol, each layer in OSI model executes a well defined function. When the data and information transmission taking places between the two nodes, a protocol is needed to describe the way of sending and receiving and the rate of data transmission. In network, routing is nothing but the selection of paths along which to send network data. A communication protocol is a group of formal rules and regulations describing how to transmit data in a network. A routing protocol is a protocol which specifies how the network routers communicates with each other that enables them to select multihop routes between any two nodes on a communication network [18,19].

2.2 Approaches for Routing Protocols

Various routing energy efficient protocols have been developed for wireless sensor networks. Protocols such as clustering can enhance the performance of protocols in terms of energy efficiency and network organisation.

2.3 Clustering

Clustering is an energy efficient protocol that has been implemented in many communication protocols for wireless networks [20–24]. In a clustering-based protocol, nodes are being classified into several clusters. Each cluster is constituted by one cluster head and numbers of member nodes. In this protocol, all the member nodes of the cluster send their data to their respective cluster head which then forwards the aggregated data to the base station. The base station then interact with outside world through Internet or satellite links. The cluster head performs data processing such as data aggregation, before forwarding the processed data. Clustering helps to reuse bandwidth and thus increases the system capacity. In addition, the clustering method helps to obtain the hierarchical structure which enable to manage energy efficiently of the network as well as to manage topology of the network with large numbers of nodes.

In clustering-based protocol of wireless sensor networks, network nodes are classified into various clusters. Then the members node transfer their data to the cluster heads at the time of each frame of data transfer, and then the cluster heads relay the data to the base station. Since data located at nodes which are very close to each other are highly correlated, the cluster head aggregates the data from each member node to reduce the amount of data that must be transmitted to the base station. As a result, the energy required for data transmission can be decrease. Since the cluster heads are to transmit the data to the base station through the shared wireless channel, if the cluster heads cannot aggregate the data, then there will be no benefits to use this approach over an other traditional approach where each node transmits its data directly to the sink or the base station.

2.4 Related Works

W.R. Heinzelman, A.P. Chandrakasan and H. Balakrishnan [1] introduced Low Energy Adaptive Clustering Hierarchy (LEACH) protocol in the year 2000 which is one of the most popular hierarchical clustering algorithms for sensor networks.

The concept here is to make clusters of the sensor nodes depending upon the received signal strength and finally use local cluster heads as the routers to the sink. The energy is being saved by this method since the transmissions are done by cluster heads rather than all the sensor nodes. Optimally, the number of cluster heads is calculated to be $.05 \times$ the total number of nodes. The activities like data fusion and aggregation are done locally to the cluster. To balance the energy consumption of nodes, cluster heads keep changing randomly over the time. This decision is done by the node through choosing a random number between 0 and 1. The particular node is considered as a cluster head for the current round if the number is less than the threshold value of that node.

S. Lindsey and C. Raghavendra [6] proposed Power Efficient Gathering in Sensor Information Systems (PEGASIS) protocol in the year 2002 which is an enhanced version of LEACH. Instead of forming clusters, the protocol is truly based on forming chains of sensor nodes. One node is responsible for routing the aggregated data to the sink which acts as the cluster head. Every other node aggregates the collected data with its own data, and then forwards the aggregated data to the next node in the ring. The only difference from the LEACH is to employ multi hop transmission and choosing only one node to transmit to the base station or the data sink. The advantage of this method is that it removes the overhead caused by dynamic cluster formation. As a result, PEGASIS outperforms the LEACH. However, there are some disadvantages as well i.e. excessive delay is introduced for distant nodes, especially for large networks.

A. Manjeshwar and D. P. Agrawal [25] introduced Threshold sensitive Energy Efficient sensor Network Protocol (TEEN) protocol in the year 2001. The idea is to form clusters of the closer nodes with the cluster heads to transmit the collected data to its one upper layer. In forming the clusters, cluster heads announces two threshold values. First one is hard threshold which is the minimum possible value of an attribute to trigger a sensor node. Another is the hard threshold that makes the nodes transmit the event, if the event occurs in the interested areas. So, there is a significant reduction in the transmission delay occurs. The protocol is very much suitable for time-critical applications.

A. Manjeshwar and D. P. Agrawal [26] introduced Adaptive Threshold sensitive Energy Efficient sensor Network Protocol (APTEEN) protocol in the year 2002. The protocol is an enhancement of TEEN which aims to capture both periodic data collections and time-critical events. The network backbone is same as the TEEN. The cluster heads broadcast attributes, the threshold values and the transmission schedule to all nodes after the cluster formation takes place.

It is also the responsibility of the cluster heads to aggregate the data since it decreases the amount of data being transmitted. So energy is consumed in this task.

Comparing to energy dissipation and network lifetime, TEEN produced better performance than LEACH and APTEEN. The major demerits of TEEN and APTEEN are to implement the threshold-based functions and dealing with attribute based naming of queries. Also, the overhead and complexity of forming clusters in multiple levels are its major disadvantages.

G. Smaragdakis, I. Matta and A. Bestavros [27] introduced Stable Election Protocol (SEP) protocol in the year 2004. This protocol is an increment version to the LEACH Protocol. The protocol is a heterogeneous aware protocol that is based on weighted election probabilities of each node in order to become cluster head as per their respective energy. This mechanism ensures to elect the cluster head randomly and distributed based on the fraction of energy of each node guaranteeing a uniform use of the nodes energy. Here, there are two types of nodes (two tier clustering or two level hierarchies) that are considered.

In the year 2005, M. Ye, C. Li, G. Chen and J. Wu [21] proposed Energy Efficient Clustering Scheme (EECS) protocol. The protocol is a novel clustering scheme which is used for periodical data gathering applications in wireless sensor networks. The cluster heads election is done with more residual energy nodes through local radio communication. Here, a constant number of candidate nodes are elected and competes locally without iteration for cluster heads based on the residual energy. The protocol also ensures a uniform cluster heads distribution in the wireless sensor network. Further, to maintain the load balancing among cluster heads, a novel approach is introduced. But, the requirement of global

knowledge about the distances between the cluster heads and the base station in the wireless sensor network is being increased by the protocol.

Q. Li, Z. Qingxin and W. Mingwen [28] in 2006, proposed Distributed Energy Efficient Clustering (DEEC) protocol which is a cluster based protocol for two level and multi level energy heterogeneous wireless sensor networks. In this method, the cluster heads selections are done through the probability which is based on the ratio of residual energy of each node and the average energy of the network. In this, those nodes with high initial energy and residual energy are having more chances to become cluster heads compared to nodes with low energy.

In the year 2007, Xianghui Wang and Guoyin Zhang [29] proposed Distributed Election Clustering protocol (DECP). The protocol is a heterogeneous aware clustering protocol that elongates the stable region of the wireless sensor network, which are based on remaining energy and communication cost to elect suitable cluster-head nodes. When there are imbalances energy available in the local area in the network, high energy node is considered first of all, to be the cluster head and when there are balanced energy, communication cost is considered next as the criteria to elect cluster head. This mechanism is very important for many applications where the sensor network feedback is reliable.

DECP produces long stable region than the traditional protocols such as LEACH [1] and SEP [27].

Chapter 3

The Proposed model in Clustering protocol

This chapter introduces a new energy efficient clustering protocol. It has the cluster head selection algorithm, a cluster formation phase and finally the data transmission phase.

3.1 System Model

We described here about the system model including network model and energy model used in the introduction of our new protocol. The initial energy level of nodes are considered as different;

1. All nodes are fixed and immobile.
2. The base station is fixed at the centre of the network. We also assume that network nodes are not location aware (i.e. not equipped with the GPS-capable antenna). In addition, each node has equal processing power to enable the different protocols and data processing tasks. The nodes in the network are left unattended after deployment. As a result, battery recharging of nodes in the network is not possible.

3.1.1 Network model

To develop the new protocol, the network model consists of the operating environment which consists of N number of nodes and one base station. Nodes are randomly installed in a 100×100 area with the base station assumed to be located at the centre of the network area. The sensor nodes periodically sense the environment and send the sensed data to the base station. And on the other hand, the base station is responsible for getting data from the sensor nodes and then presented the user a condition of the environment where the nodes are sensing. Some of the characteristics of the network model are as follows:

1. All nodes have the equal capabilities of sensing, processing and communicating data;
2. The nodes are energy constrained;

3.1.2 Energy model

We considered the first order radio communication model introduced in [7] as the radio energy module to assess the energy dissipation. This radio model has the following three modules i.e. the transmitter, the power amplifier, and the receiver. The transmitter dissipates energy to function the transmitter circuitry. The power amplifier dissipates energy for transmitting data and the receiver module dissipates energy to run the receiver circuitry for receiving data [7]. There are basically two propagation models-

1. free space propagation model and
2. two-ray ground propagation model [7].

The free space propagation model is the propagation model where there is direct line of sight path between the transmitter and the receiver.

The two ray ground propagation model is the model where the propagation between the transmitter and the receiver is not direct and the electromagnetic

wave will bounce off the ground and arrive at the receiver from different paths at different instant of time.

In the free space propagation model, the propagation loss of transmitting power is modelled as inversely proportional to d^2 , where d is the distance between the transmitter and the receiver. In the two-ray ground propagation model, the propagation loss of transmitting power is modelled as inversely proportional to d^4 .

The power amplifier can be used to amplify the transmitting power to compensate propagation loss during the transmission. Thus, the energy dissipation for transmitting an L bit message from the transmitter to the receiver at the distance d is defined as:

$$E_{Tx}(L, d) = \begin{cases} L \times (E_{elec} + L \epsilon_{fs} \times d^2), & \text{if } d \leq d_0, \\ L \times (E_{elec} + L \epsilon_{mp} \times d^4), & \text{if } d \geq d_0 \end{cases}$$

where E_{Tx} is the energy dissipated by the transmitter and E_{elec} is the energy dissipated per bit to run the transceiver circuit. The parameters ϵ_{fs} and ϵ_{mp} depend on the transmitter amplifier model used in the algorithm.

The amplifier parameter for the free space propagation model is ϵ_{fs} . The amplifier parameter for the two-ray ground propagation model is ϵ_{mp} . The cross over distance, d_0 , can be obtained from:

$$d_0 = \sqrt{x/y} \text{ where } x = \epsilon_{fs} \text{ and } y = \epsilon_{mp}.$$

If the distance between the transmitter and the receiver is larger than the cross-over distance, the two ray ground model is used otherwise, the free space model is considered to measure the energy dissipation. Energy required for receiving an L bits message is: $E_{Rx}(L) = LE_{elec}$. We use the same parameters as in [8]: $E_{elec} = 50\text{nJ/bit}$; $\epsilon_{fs} = 10\text{pJ/bit/m}^2$; $\epsilon_{mp} = 0.0013\text{pJ/bit/m}^4$.

3.2 Problem Statement

Normally, large number of nodes are being deployed in the wireless sensor network monitoring field. So, the data flow in the network is considerably large which will involve significant energy dissipation for nodes. In addition, similar types of data

may be found in the closely located nodes which requires aggregation of data. The energy consumption of nodes in the network is different from node to node due to locations and some other factors of the nodes in the network. Also, most of the above protocols mentioned in the related work have assumed the network environment to be homogeneous in nature i.e. all the nodes in the network are same in terms of energy level. But, these assumptions are not feasible when we talk about real life scenario.

So, in order to let the protocol to more closely work with the real life scenario, we need to develop a new protocol known as heterogeneous aware clustering protocol where the multiple number of nodes classifications are being considered. Since, the nodes are energy constraint, the clustering protocol should be able to minimise the energy consumption of data transmission from nodes to the base station. Therefore, the problems that need to be considered in the design of clustering protocol for wireless sensor network can be defined as :

1. How to effectively and efficiently organised the numerous nodes in the heterogeneous aware network in order to reduce the energy consumption of nodes
2. How to balance the energy consumption of nodes so as to increase the stable region of the network

3.3 Proposed solution to the energy-efficient Problem

The main target of the problems above is to manage the energy efficiently in a large wireless sensor network where the data is highly correlated. The clustering method is a sensible approach for a large wireless sensor network. The clustering technique can efficiently organized numerous nodes, aggregate data and reduces energy dissipation of nodes.

The protocols that use Multi-level Clustering concept where the multiple

classification of nodes category are available in terms of energy level can produce better clusters that requires less energy for data transmission. The cluster heads then forward the aggregated data to the base station and base station finally communicates with the remote controller node through satellite link or internet. Using an efficient Multi level Clustering Protocol, can minimize the energy dissipation of data transmission from cluster heads to the base station.

The Multi level Clustering Protocol(MLCP) has two variants-

- Multi level Election Clustering protocol(MLECP) and
- Multi level Randomized protocol(MLRP)

The Multi level Election Clustering Protocol(MLECP) consists of the following-

- classifying the nodes into various types or categories based upon the energy level
- Cluster head selection algorithm based on the ratio of the current remaining energy of a node divided by the number of its neighbours to the sum of all its neighbouring nodes energy including itself.
- a cluster formation scheme that aims at balancing the energy load among cluster heads nodes and finally,
- data transmission from cluster heads to the base station.

The Multi level Randomized Clustering Protocol(MLRCP) consists of the following-

- classifying the nodes into various types or categories based upon the energy level
- random number generation based cluster head selection algorithm
- cluster formation scheme that aims at balancing the energy load among cluster heads nodes and finally,
- data transmission from cluster heads to the base station.

3.4 Detail of the Proposed protocol

3.4.1 Multi level Election Clustering Protocol(MLECP)

Firstly, the given nodes in the network are classified into different category in term of energy levels namely, Super advanced nodes, Advanced nodes, Intermediate nodes and Normal nodes. Super advanced nodes have the highest energy. Next highest energy nodes are Advanced nodes and Normal nodes are the those nodes with the least energy level.

The algorithm for classifying into different category are as follows-

Algorithm 1 Algorithm: Multi classification of nodes for MLECP

```

1: for  $i=1$  to  $n$  do
2:    $\text{temprnd0}=i$ 
3:   if  $\text{temprnd0} \geq (x + m + m1) * (n + 1)$  then
4:      $S(i).E \leftarrow E_o$ 
5:      $S(i).ENERGY \leftarrow 0$ 
6:   end if
7:   if  $\text{temprnd0} < (x + m + m1) * (n + 1)$  then
8:     if  $\text{temprnd0} > (m1 + m) * n$  then
9:        $S(i).E \leftarrow (E_o * (1 + b))$ 
10:       $S(i).ENERGY \leftarrow 1$ 
11:     end if
12:   end if
13:   if  $\text{temprnd0} < (m + m1) * (n + 1)$  then
14:     if  $\text{temprnd0} > (m1) * n$  then
15:        $S(i).E \leftarrow (E_o * (1 + a))$ 
16:        $S(i).ENERGY \leftarrow 2$ 
17:     end if
18:   end if
19:   if  $\text{temprnd0} < (m1 * n) + 1$  then
20:     if  $\text{temprnd0} > (m1) * n$  then
21:        $S(i).E \leftarrow (E_o * (1 + a_1))$ 
22:        $S(i).ENERGY \leftarrow 3$ 
23:     end if
24:   end if
25: end for

```

Cluster head selection algorithm

In the clustering-based protocol, the nodes are arranged into local clusters. Each cluster consists of one cluster head and number of member nodes which belongs to the same cluster. All non cluster head nodes should transmit their data to the cluster head, while the cluster head must forward the received data from all the cluster members to the remote base station after performing data aggregation. Therefore, being a cluster head is much more energy consuming than being a non-cluster-head member node.

Cluster head selection in MLECP

In our protocol, cluster head selection algorithm based on the ratio of the current remaining energy of a node divided by the number of its neighbours to the sum of all its neighbouring nodes energy including itself is being proposed. The aim of the protocol is to choose the cluster heads that ensure the uniform energy load distribution of nodes in the network so as to increase the stable region of the network and finally enhanced the life time of the network with efficient energy usage.

Cluster heads are the local leader in their own clusters. They performed many tasks like collecting data from member nodes and forwarding processed data to the base station. This procedure incurred a lot of energy consumption. Thus, the information of neighbouring nodes, the distance between cluster head and member nodes are all crucial issues when choosing cluster heads. In addition, in order to choose nodes with more energy to be the cluster heads, remaining energy of nodes is considered for cluster head selection in the protocol. In case, the energy levels are tied then the minimum distance cost of the node will decide which node to be the next cluster head.

The algorithm for cluster head selection are as follows-

Algorithm 2 Algorithm: Selection of cluster head in MLECP

```

1: for  $i=1$  to  $n$  do
2:    $j=S(i).nbr$ 
3:    $S(i).E_j = 0$ 
4:    $S(i).D_j = 0$ 
5:   for  $k=1$  to  $j$  do
6:      $neighbour(i)=neighbour(i) + 1$ 
7:      $S(i).E_j = S(i).E_j + S(S(i).n(k)).E$ 
8:      $S(i).D_j = S(i).D_j + (d(i, j))^2$ 
9:   end for
10:   $temp = S(i).E/S(i).nbr * (S(i).E_j + S(i).E)$ 
11:   $S(i).MPC = 1 - temp$ 
12:   $S(i).C_{min} = (1 - S(i).MPC) * (S(i).D_j/S(i).nbr)$ 
13: end for

```

Cluster Formation

The cluster formation of this protocol targeted at balancing the energy load of cluster heads. Once the nodes have been elected as cluster heads, they will invite the other non cluster head member nodes in the network to join the clusters.

To achieve this, each cluster head broadcasts an invitation message to all other members nodes using a non-persistent carrier sense multiple access (CSMA) MAC protocol (as shown in Figure 3.1). The cluster head selection technique used in our protocol ensures that the non cluster head members nodes do not need to send their data to the long distance remote base station node. Instead, they will send the data to the nearest cluster head. Then the cluster heads will take care to further forward the aggregated data to the base station.

Since some member nodes may reside in more than one neighbourhood of cluster heads, they will receive more than one invitation messages (if a cluster head receives invitation messages from other cluster heads, it will just ignore the messages). The dissipation energy mainly depends on the distance between the

two nodes and the data transmission within the cluster follows the free space energy model. Therefore, the node degree is a measurement of the intra-cluster communication cost of a cluster head. To balance the energy dissipation among the cluster heads, non cluster head members nodes will select the cluster head with minimum node degree as their cluster head in the current round.

The members node must inform the cluster head that it will be a member of that cluster head once if that node has decided that it belongs to that cluster. Then each node transmits a joining message to the chosen cluster head using a CSMA MAC protocol. The cluster heads then act as local leader node to coordinate the data transmission in their clusters. On the basis of the information of joining nodes, the cluster head creates a time division medium access (TDMA) schedule and forward this schedule to the joined nodes. Once the TDMA schedule is known to all nodes in the cluster, the set-up phase is considered to be complete and then the transmission phase of the wireless sensor network can begin.

The algorithms are as follows-

Algorithm 3 Algorithm: Formation of cluster in MLECP

```

1: for  $i=1$  to  $n$  do
2:   if  $S(i).E > 0$  then
3:     if  $S(i).type == N$  then  $md=100000$ 
4:       for  $j=1$  to  $l-1$  do
5:          $dch(i, j) = \text{sqrt}(((S(i).x - S(ch(j)).x)^2) + ((S(i).y -$ 
            $S(ch(j)).y)^2))$ 
6:           if  $dch(i, j) < md$  then
7:              $md = dch(i, j)$ 
8:              $S(i).C = ch(j)$ 
9:           end if
10:        end for
11:      end if
12:    end if
13:  end for

```

3.4.2 Multi level Randomized Clustering Protocol

The Multi level Randomized Clustering Protocol(MLRCP) consists of the following procedures-

- classifying the nodes into various types or categories based upon the energy level
- random number generation based cluster head selection algorithm
- cluster formation scheme that aims at balancing the energy load among cluster heads nodes and finally,
- data transmission from cluster heads to the base station.

The algorithm for multi classification of nodes in terms of energy level in this case will be same as in MLECP but the cluster head selection operation activities are different.

Cluster head selection in MLRCP

The cluster head selection in this technique is done through a random number generation for each node between 0 and 1 and then compared with the threshold value of that node. The threshold value of the node is calculated as follows-

$$T(n) = \begin{cases} \frac{p}{(1-p*(r \bmod \frac{1}{p}))} & \text{if } n \in G \\ 0 & \text{Otherwise} \end{cases}$$

where p is the percentage of cluster heads(e.g. 0.05), r is the current round, and G is the set of nodes that have not become cluster heads in the last 1/p rounds so far.

If the random number generation by a node is less than the threshold value, then that particular node is selected as the cluster head else not.

Formation of cluster in MLRCP

In this section, cluster formation of MLRCP is being described. Based on the nearest cluster head for each node in the network, a cluster head will be chosen

by the non cluster head members node and thus form the cluster.

Transmission of data

Once the above subsections are completed, we conclude that the cluster set up is completed and then the next phase called steady phase which is the data transmission section that involves the data transmission between the nodes and the Base station are being initiated. When all these procedures are completed, we can say that a round of the network is completed and repeat the above same procedure for the next round of the network operation.

3.5 Operation of the MLCP Protocol

The operation of MLCP protocol is divided into rounds. As shown in Figure 3.2, each round begins with a set-up phase, where the clusters are created and organised, and then being followed by a transmission phase, where the data transmissions between the nodes and the base station occur. The procedure of the protocol operation is as follows:

1. Network initialisation.
2. Cluster heads are selected on the basis of residual energy of nodes and its minimum transmission cost.
3. Clusters are created or formed by organising non cluster head nodes into clusters.
4. Cluster member nodes are allowed only to transmit data to their associated cluster heads rather than directly to the base station
5. Cluster heads then forward the processed data to the base station.
6. After the base station received the data from all the cluster heads, a round of the network is complete and the next round will begins immediately.

The steps shown in Figure 3.2 helps the protocol to efficiently and effectively route the data from sensor nodes to the base station.

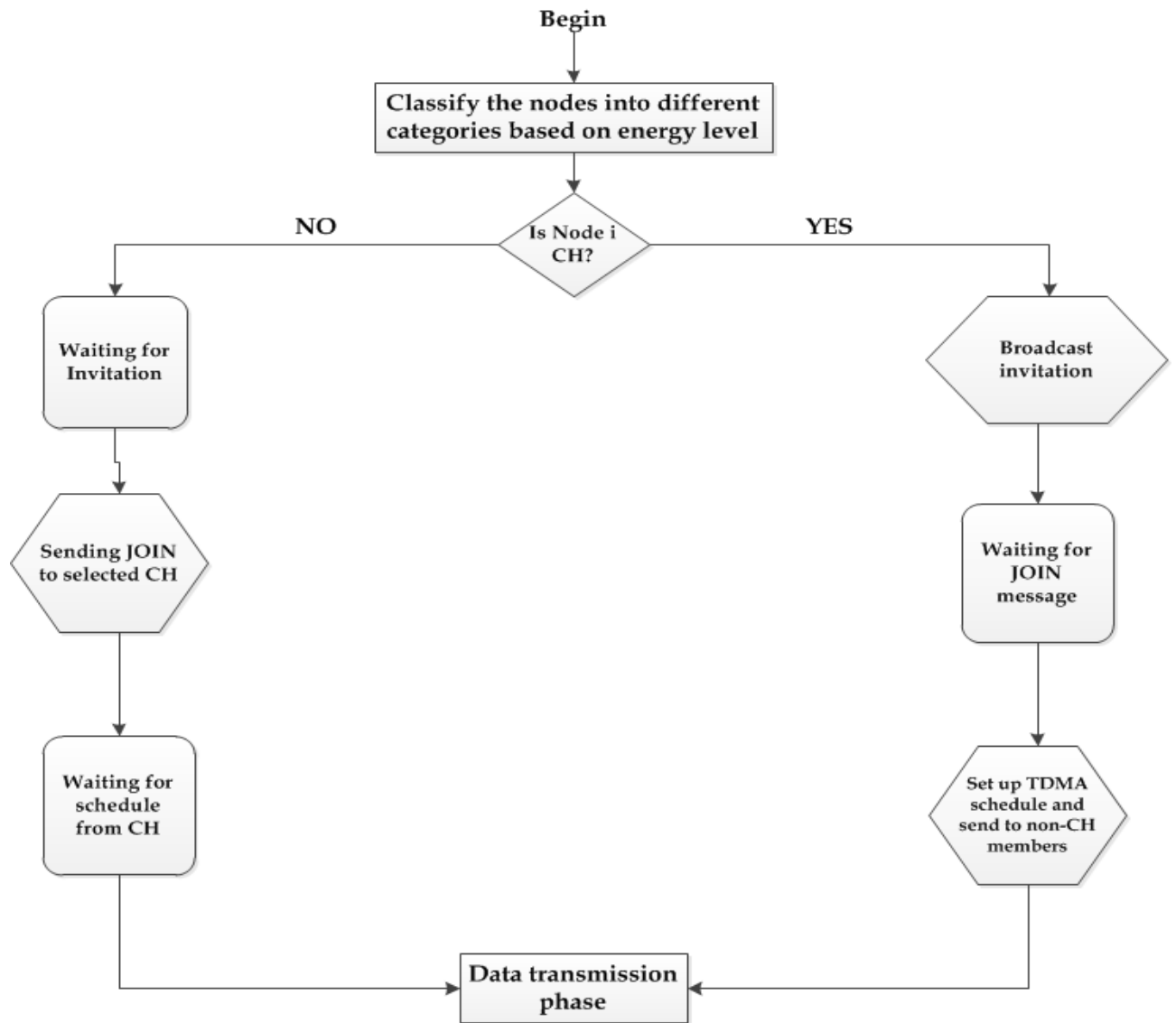


Figure 3.1: Flow graph of cluster formation for MLCP

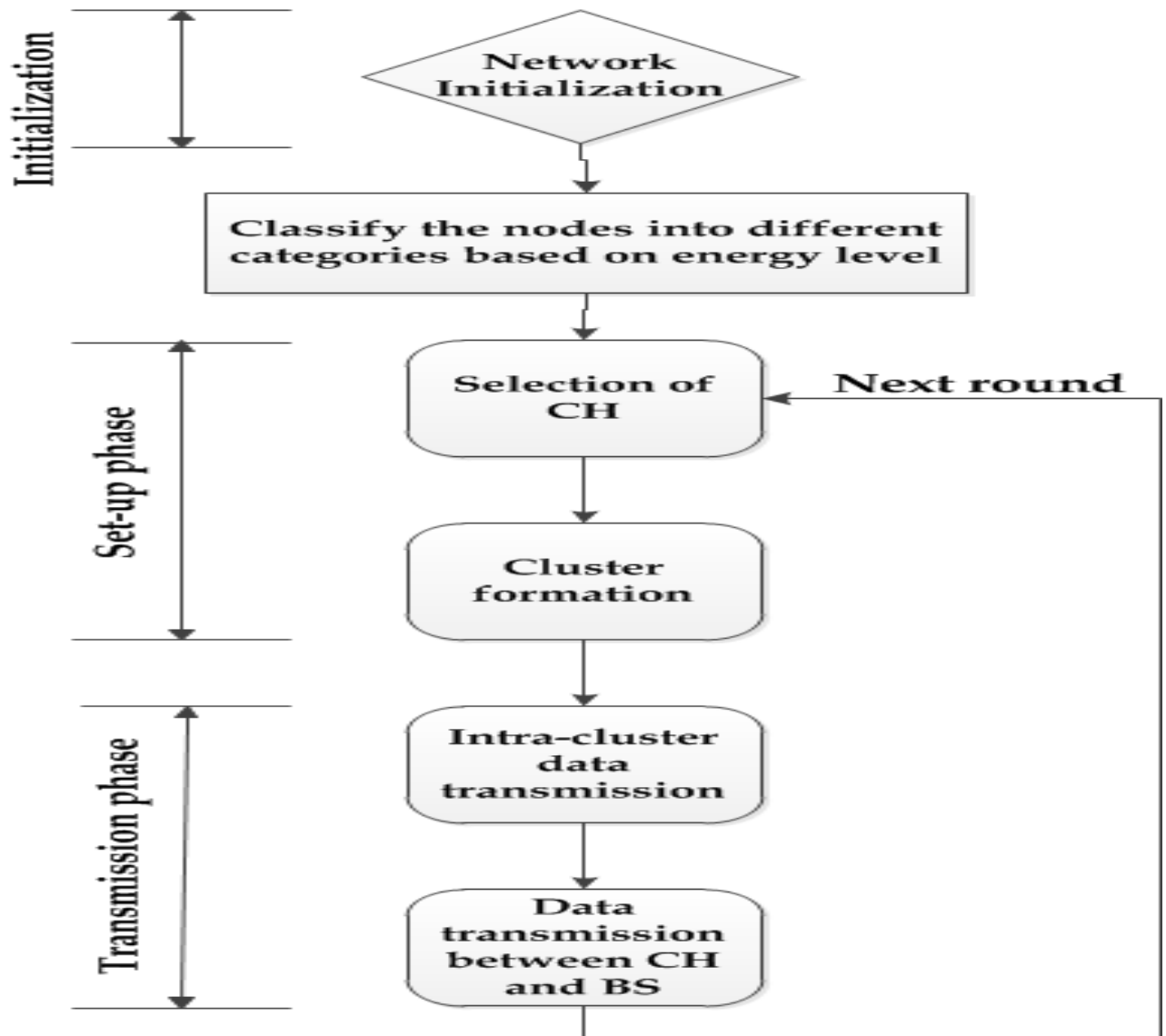


Figure 3.2: Network operation of MLCP protocol

Chapter 4

Performance Evaluation of MLCP by Simulation

Simulation is a tool to evaluate the performance of protocols under different environment and conditions. In this Chapter, the Multi-level Clustering Protocol which is energy-efficient clustering technique presented in Chapter 3 is evaluated on a simulation platform. The performance of the protocol is compared with those of the two existing protocols in terms of the network lifetime.

4.1 Simulation Set-up

We run the protocol simulations using MATLAB. MATLAB is a software package for high-performance numerical computation and visualization. It provides an interactive environment with hundreds of built-in functions for technical computation, graphics and animation. Above all, it also provides easy extensibility with its own high-level programming language. The name MATLAB stands for Matrix laboratory . The main features of MATLAB are:

1. It supports high level graphics programming(for examples like 2-D Graphics, 3-D Graphics, Color and Lighting,Animation and Audio and Video)
2. It supports computations like Linear algebra, data analysis, signal

Processing, Polynomials and Interpolation etc

3. It supports external interfaces(like interfaces with C, java and Fortran Programs)

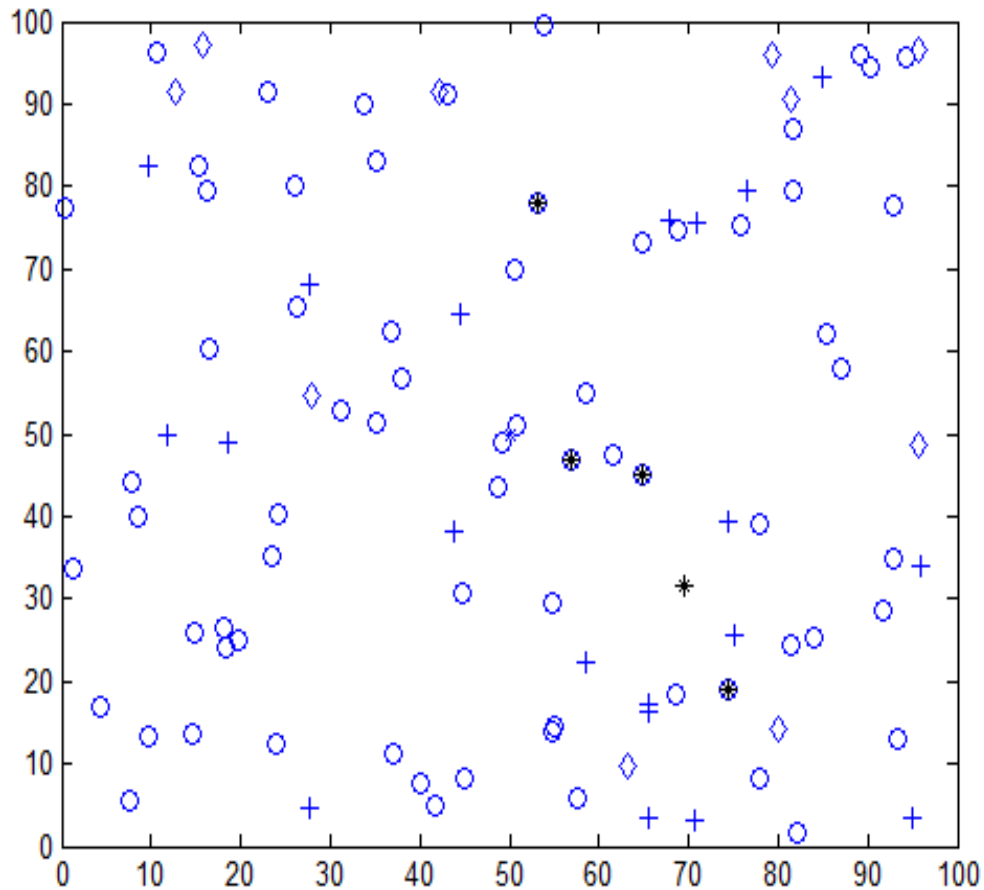


Figure 4.1: Initial set up of sensor nodes in MLCP with 3 energy level

Figures 4.1 and 4.2, shows the initial sensor nodes set up in an area of 100×100 m with the base station assumed to be located at the centre of the network. The figures shows the multiple classification of nodes that are being used in the network monitoring field. In figure 4.1, there are three nodes represented by circle, + and

Table 4.1: Simulation parameters

<i>Parameter</i>	<i>Value</i>
Area	100 × 100
Nodes	100
Base Station	(50,50)
Initial Energy	0.2J
E_{elec}	50nJ/bit
ϵ_{fs}	10pJ/bit/m ²
ϵ_{mp}	0.0013pJ/bit/m ⁴
EDA	5nJ/bit/message
Packet Size	2000 bits

diamond symbols. The circle indicates the normal node, where there are least energy, + indicates the intermediate nodes which have higher energy than normal nodes and diamond shape represent advanced nodes which have the highest energy. In figure 4.2, we have four classification of nodes unlike the case of figure 4.1. Here, circle represent normal node, . represent intermediate nodes, + represent advanced nodes and diamond shape represent super advanced nodes. Super advanced have the highest energy while normal nodes have the least energy.

The data packet size used in the simulations are 2000 bits . This means each node sends periodically 2000 bits data packet to the base station and the advertising message broadcast from a cluster head is 64 bits. The calculation of energy consumption for data transmission is based on the energy model presented in Section 3.1.2. The parameters utilized in the simulations are summarized in table 4.1

4.2 Performance Evaluation

In this section, we implemented the LEACH Protocol, DECP protocol and finally our proposed protocol MLCP. As mentioned already, the proposed protocol MLCP has two types- MLECP and MLRCP protocols. Each of our proposed protocol is compared with the existing system using the performance parameter called the network life time . The network operation of LEACH, DECP, MLECP and MLRCP are all divided into rounds. One round is the time period from the set-up phase starting time to the completion time of the data transmission phase when

by the time, all the nodes send data at the base station.

Network life time is the time period up to which a certain amount of nodes are still survived or all the nodes are survived. For a certain application, every node is required to work in order to ensure good coverage of the network. Thus the network life time is measured by the life time of the shortest living node. Therefore, the number of rounds until the first node die or until some fixed percent of nodes dies are used to evaluate the performance of the system in term of network life time in our protocols.

4.3 Simulation Results

For our simulations, we started with the nodes classifying into some groups in which each group nodes have initial distinct energy level in term of joules. We recorded the number of dead nodes in each round of the network so that we can calculate the number of alive nodes in each round. This finally helps to evaluate the performance of the system.

Fig4.3, fig4.4 and fig4.5 given below shows that MLECP outperformed better as compared to the existing protocol DECP in term of stable region and network life time. As shown in the below three graphs, the graph of all proposed models i.e. 3level MLECP and 4level MLECP are found to be located above the existing system DECP. This shows that the number of alive nodes against the number of rounds in each of the proposed model is higher than the existing system. MLECP increases the ratio of stable region in network lifetime. MLECP select high energy nodes to be the cluster-head first for load balancing in the network and as a result, low energy nodes spend less energy than high energy nodes. So MLECP helps to sustain the survival of low energy nodes more longer time and hence prolongs the stable region of the wireless sensor networks and finally increase the life time of the network.

Fig4.6, fig4.7, fig4.8 and fig4.9 shown below shows that the MLRCP also performed better than the existing system LEACH because as shown in the below figure, the graph of all proposed models are found to be located above the existing system. It signifies that, the number of alive nodes against the number of rounds in each of the proposed model is higher than the existing system. Obviously, the node with higher more remaining energy given the opportunity to become cluster head will help to increase the stable region of the network by making the low energy nodes to survive for a longer period of time and hence finally, increased the overall life time of the network. MLRCP protocol also balance the energy consumption of nodes by distributing the CH selection of a node randomly for every round. As a result, it outperforms better as compared to homogeneous LEACH protocol. But,the concept of remaining energy to select CH in this case has no role at all where the advance nodes have more opportunity to be the cluster-head. MLECP has the best performance in term of remaining energy criteria to select CH, because MLECP do not use random mechanism for cluster-head selection, thus MLECP could accurately select the high energy node with very low communication cost to be the cluster-head, and implement the load balancing in WSN. Hence, overall our protocol gives better performance as compared to existing system.

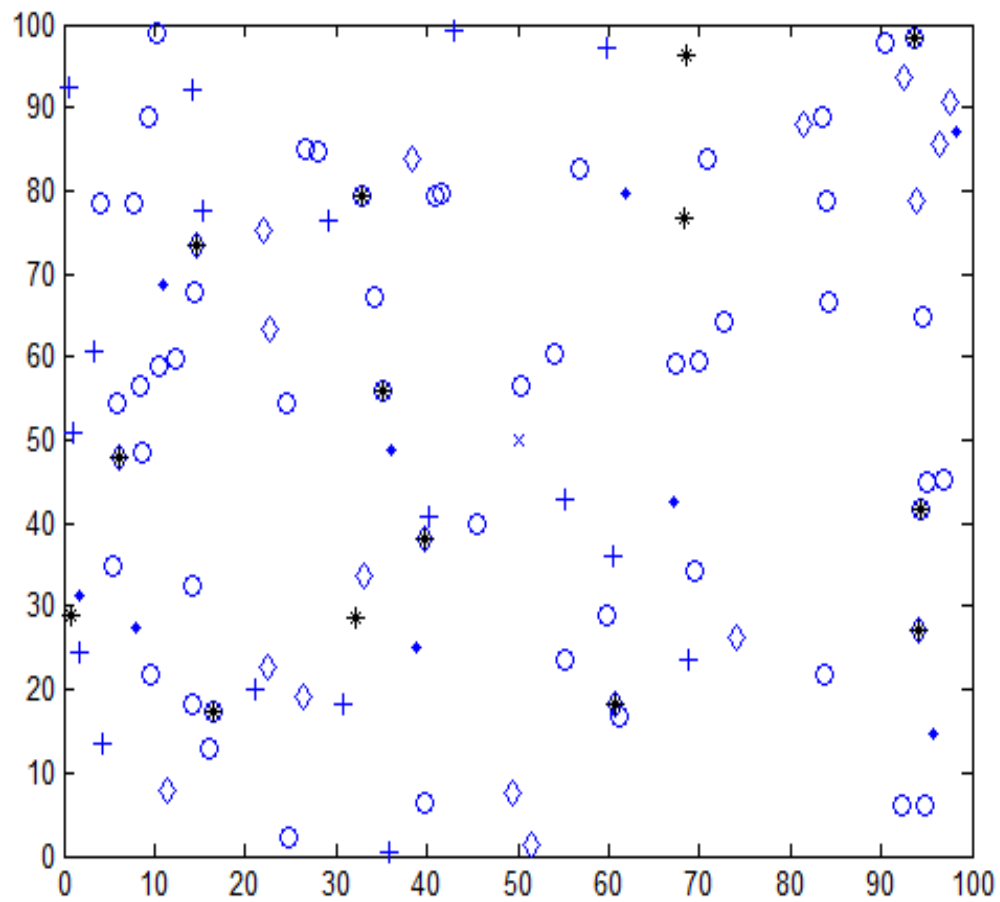


Figure 4.2: Initial set up of sensor nodes in MLCP with 4 energy level

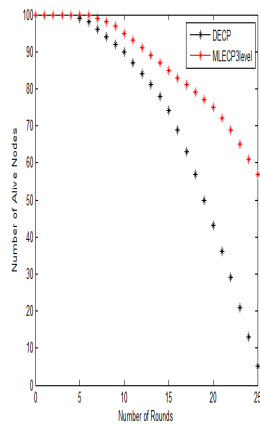


Figure 4.3: Lifetime of the MLECP algorithms for 3 level and DECP

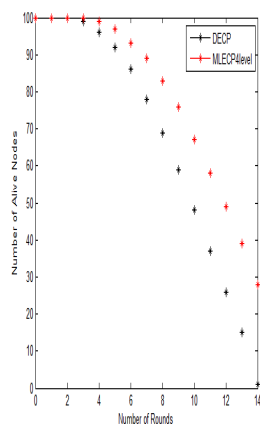


Figure 4.4: Lifetime of the MLECP algorithms for 4 level and DECP

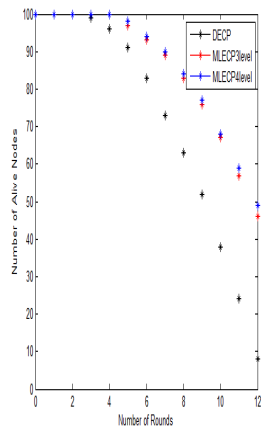


Figure 4.5: Lifetime of the MLECP algorithms for 3,4 levels and DECP

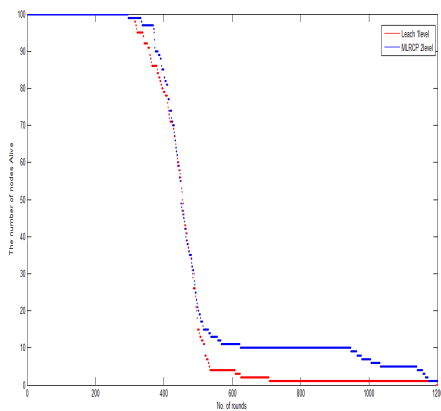


Figure 4.6: MLRCP 2level and LEACH life time

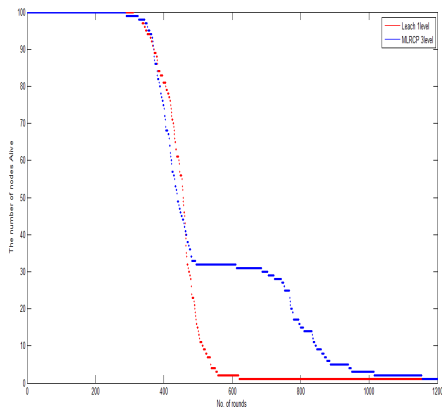


Figure 4.7: MLRCP 3level and LEACH life time

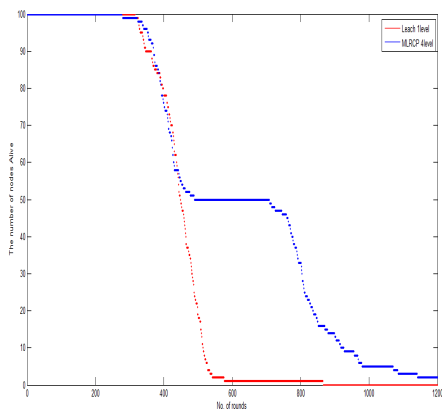


Figure 4.8: MLRCP 4level and LEACH life time

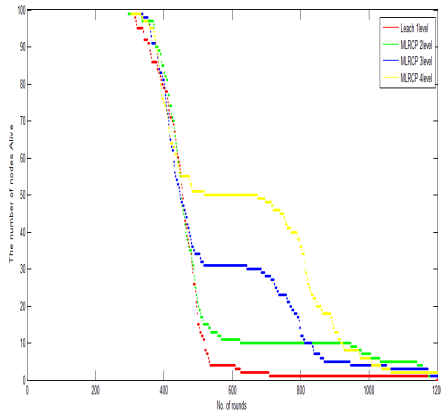


Figure 4.9: MLRCP 1,2,3 and 4 levels and LEACH life time

Chapter 5

Conclusion and future scope

In this thesis, Multilevel Clustering Protocol (MLCP) is proposed for heterogeneous aware Wireless sensor network. Here, we introduced more than two types of different categories of nodes in terms of energy levels: 3-tier energy level nodes and 4-tier energy level nodes. In each of the variants of MLCP i.e MLECP and MLRCP protocol, we have evaluated the performance of our protocol as compared to the existing protocols LEACH and DECP. It is observed that our protocol gives better performance and results in terms of network stable region, alive nodes and the life time of the network in comparison to the existing protocols. Hence, our protocol is a better protocol.

Though our protocol MLCP gives better and improved performance as compared to DECP and LEACH, if we increased the level of nodes classifications in term of energy level more and more, the complexity of the system will also be increased which ultimately affects the understandability and the analysis of the system. So, in the near future, we believe that if we have the optimal number of nodes classification, the system clarity and understandability will increase and will perform better as well.

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Dissemination

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